U.S. Department of Energy
Energy Efficiency
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NANOMANUFACTURING

Critical gateway for delivering the energy benefits of nanotechnology

The American manufacturing sector provides materials for subsequent use in all other sectors of the economy. Recognizing the value of the unique material properties achievable through nanotechnology, the U.S. government has led global investment in this science. The U.S. Department of Energy's Industrial Technologies Program is now advancing the capability to efficiently incorporate nanomaterials into commercial processes and products.

NANOMANUFACTURING

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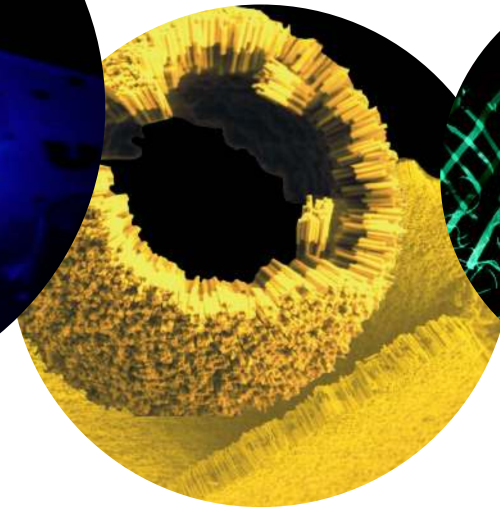

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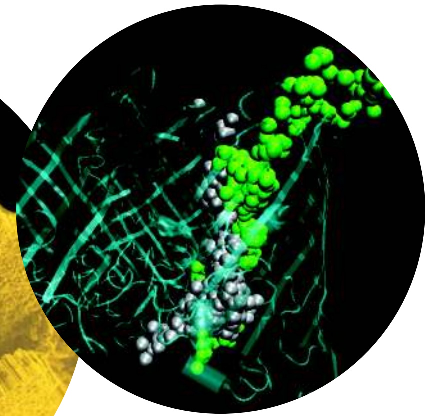

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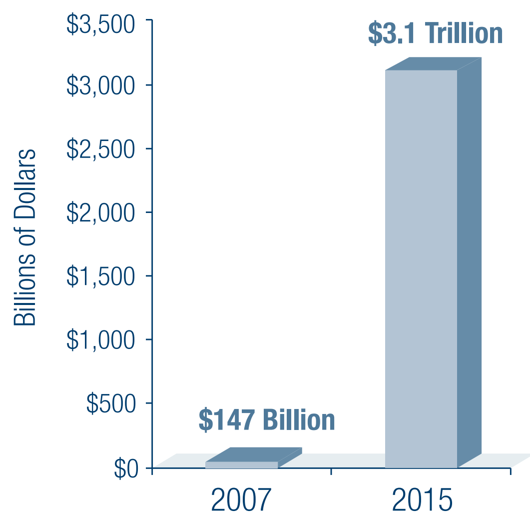
UNLOCKING the POWER

The U.S. Department of Energy's Industrial Technologies Program (ITP) conducts research and development (R&D) to accelerate the use of nanotechnology in U.S. manufacturing products and processes. This nanomanufacturing R&D can speed the introduction of nano-enabled products into global markets, increasing energy efficiency, energy supply, and U.S. competitiveness.

Enormous Economic Potential

Governments around the globe are investing heavily in nanotechnology in an effort to address some of the world's toughest challenges, improve lives, and stimulate economic growth. The potential economic benefits of technology leadership in this field are huge. While manufactured goods incorporating nanotechnology were valued at about $147 billion in 2007, this value is expected to grow to $3.1 trillion by 2015.

Manufactured Goods Incorporating Nanotechnology



Source: Lux Research

Energy Benefits and Other Advances

Nanomanufacturing is expected to contribute to the success of the nation's major energy and climate initiatives. Applications in the chemicals, refining, maritime, and automotive sectors alone have the potential to save up to 1.1 quadrillion Btu per year, avoiding emissions of more than 60 million metric tons of carbon dioxide annually. Enabling the use of nanotechnology to improve U.S. manufacturing processes and products will also open global markets for nano-enabled solutions for energy generation, storage, and use.

U.S. Investment in Global Context

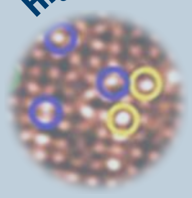
Global investment in nanotechnology rose to nearly $13.5 billion in 2007. The U.S. government has been a long-standing leader in funding for nanotechnology, investing $1.4 billion in 2007 alone. Other nations are now rapidly increasing their investments and encroaching on this lead. While other parts of the world have emphasized applied R&D to hasten commercial production of nano-enabled products, the United States has focused more on basic research. The U.S. DOE's Industrial Technologies Program is now developing the nanomanufacturing processes and product applications to begin capitalizing on the vast U.S. investment in this evolving field.

Advances in Cost-Effective Nanomanufacturing Can Deliver Diverse Energy Benefits

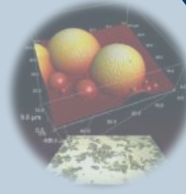
Energy Supply

- Efficient and cost-effective solar cells
- Improved wind turbine efficiency
- Improved heat transfer
- Magnetic liquid coolants for higher transformer loads

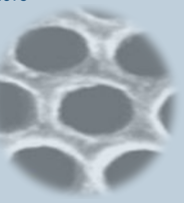
High-Efficiency Manufacturing



- Low-friction materials
- Anti-fouling surfaces



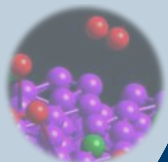
- Chip fabrication
- Highly selective separation membranes
- Efficient filters
- Advanced sensors



- Low-cost, effective catalysts for chemical manufacturing

Energy Storage

- Improved fuel cells
- Super capacitors
- Novel electrodes to boost battery efficiency and longevity
- Reversible hydrogen storage materials



Energy Efficient Products

- Window coatings
- Efficient insulation
- Solid-state lighting

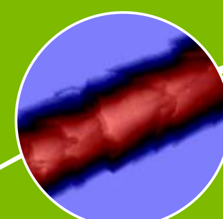
- Ultra-fast computing
- Better electrostatic protection
- Improved thermal management for electronics
- Catalysts to boost engine performance
- Lightweight materials for cars and airplanes

What is Nanotechnology?

Nanotechnology is the purposeful engineering of matter at the nano-scale, which ranges from 1 to 100 nanometers. Materials at this scale can be manipulated to achieve unique properties and functions.

How Small is a Nanometer?

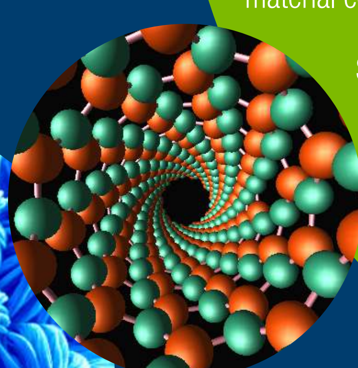
A typical human hair is around 80,000 nanometers wide.



Why the Excitement?

A nanoparticle is so tiny that its total volume is dominated by its surface area. This surface dominance increases interactions with surrounding materials, which can contribute to new and different properties in a material containing the nanoparticles.

Scientists and engineers have been learning to manipulate nano-scale materials in order to manufacture materials with different or improved properties, such as greatly enhanced strength, magnetism, or thermal conductivity.



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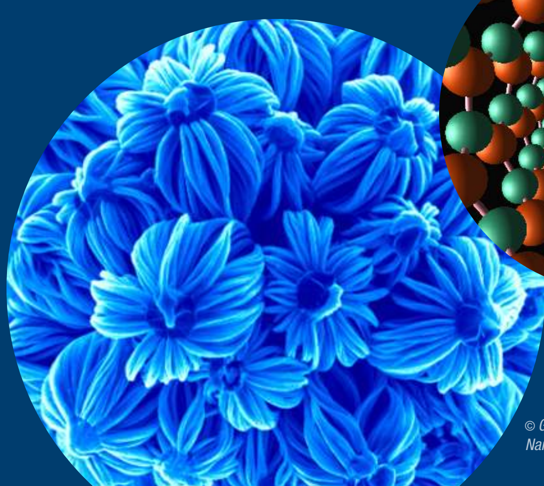

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Challenges for Nanomanufacturing

Successful integration of nanomaterials into final products typically entails resolving fundamental issues of physics and chemistry. To achieve the full potential of nanotechnology, researchers and developers must figure out how to scale up the production of promising nanostructures to a commercially useful scale without losing their unique and valuable properties. Critical challenges include the following:

Dispersion: Nanoparticles must be thoroughly and evenly dispersed within a matrix (e.g., film, coating, or resin), as clumping may make them lose their unique properties.

Contamination: Stray molecules of other materials must be prevented from adversely affecting nanomaterial properties, which are highly sensitive to atomic and molecular interactions.

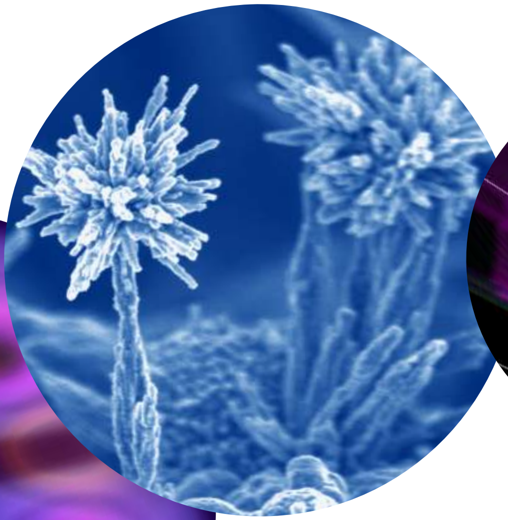
Consistency: The desired properties of nanomaterials must be consistently achieved in mass production.

Environmental, Health, and Safety protocols: The risk profiles of nanotechnology require further study and clarification.

ITP's Nanomanufacturing R&D Objectives

The Industrial Technologies Program works with industrial partners and national laboratories to develop the nanomanufacturing technologies that can deliver performance-enhancing nanomaterials into U.S. and global markets. Program activities focus on the following objectives:

- Develop low-cost manufacturing processes to expand near-term commercial use of innovative nanomaterials in
  - — Industrial processing
  - — Energy-saving and energy-producing products
- Develop technologies to enable expanded use of nanomaterials
  - — Directly as a material to enhance material performance
  - — Indirectly as an intermediate device (e.g., nanosensors for thermal management)



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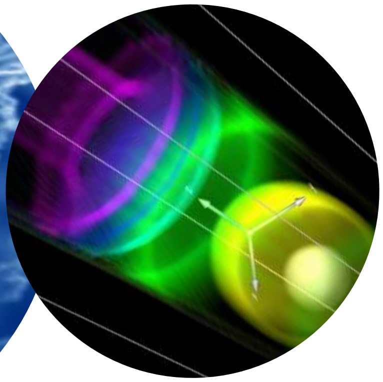
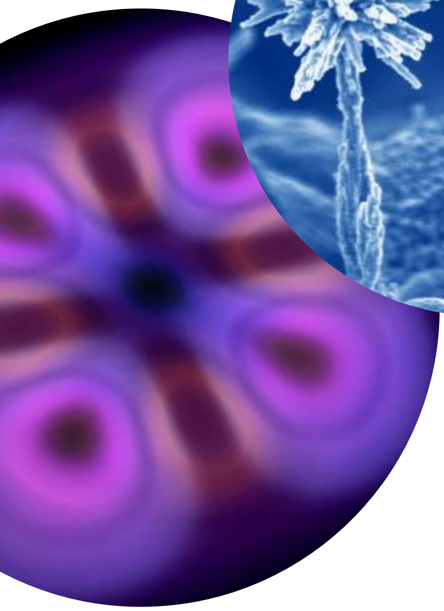


Gerhard Klimeck, Network for Computational Nanotechnology, Purdue University



Wei Qiao, David Ebert, Marek Korkusinski, Gerhard Klimeck, Network for Computational Nanotechnology, Purdue University

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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Industrial Technologies Program

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